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Climate Change-Agriculture Nexus in Pakistan: Assessing food security and Trade-offs

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ABSTRACT

This study investigates the impact of climate change on agricultural crops and food security in Pakistan. A composite index of five major agricultural crops was used as a principal component analysis for crop production, and an index of methane emission of carbon dioxide, emission of nitrous, Temperature and Precipitation was created through principal component analysis for climate change. Livestock use index as a proxy for food security. The result indicates that all the variables are indicated at the first difference; therefore, the cointegration estimation technique has been applied to determine the value of the parameters. The study found that climate change has a negative and significant impact on agriculture and food security but has a positive impact on kg/acre. Furthermore, more water availability has a negative impact on livestock and agricultural crops but is insignificant in kg/acre, whereas crop production has a positive and significant impact on climate change and tractors, but water has an insignificant impact. Tractors have a significantly negative impact on kg/acre, vectors, and livestock. Population had a significant positive impact on livestock.

Keywords: Climate Change Impact, Agricultural Crop Production, Food Security, Principal Component Analysis (PCA), Cointegration Analysis

INTRODUCTION

Pakistan has a population of more than 200 million and is situated in South Asia. It is blessed with different agro-atmospheres, geologies, and cultures. Three of the significant mountain scopes of the world are specific to the Himalaya, Karakoram, and Hindu-Kush (HKH), fringe the north by levels, fields, and beach-front regions in the south (Afzal, 2009). Exploration of environmental change in Pakistan is in its early stages, with an introductory spotlight on the potential effects of environmental change on agribusiness generation and the characteristic asset base. Regarding the effect of ecological change on agribusiness and sustainability, the National Communication on Climate Change has anticipated significant accompanying effects on horticulture in Pakistan. Pakistan is Islamic country and Islam promotes sustainability and protection of resources (S. Ali & Reardon, 2023).

Worldwide environmental change will influence the development season length of yields because of higher temperatures, S. Ali, Amjad, Kiani, and Wei (2017) noise and decreased soil dampness; adjust the phases of plant development with quickened development from the get-go in the season, influencing the amount and nature of biomass, influencing crop nuisances and sicknesses, and involve three-dimensional moves in potential territories of agrarian harvests.

The quality and measure of collection yield will be affected by natural changes in two unique ways: I) direct effects from changes in temperature, CO_2 centers, water balance, and absurd events; and ii) meandering effects through changes available for use, repeated and earnestness of disturbance and ailment flare-ups, recurrence of fire, weed intrusion, or through changes in soil

Properties (Borras Jr & Franco, 2012). The extension in temperature has a direct effect on crop loss of soil suddenness. The extension in crop evapotranspiration, when obtained together with a decrease in precipitation in the deluge supported conditions, resulted in a decrease in crop evapotranspiration in view of the obliged openness and usage of soil moisture by crops. An increase in temperature and decrease in precipitation could expand the net water and system water necessity of yields, thus constraining ranchers to make changes in editing examples to acclimate to environmental changes.

Unnatural weather changes, climatic boundaries, and CO_2 fixation would lead to changes in land-use frameworks because of changes in the development period of harvests. CO_2 discharge adversely influences horticultural efficiency and family unit welfare. In particular, CO2 discharge leads to a diminishing generation of exchanged and non-exchanged yields but not domesticated animals. Discharges compose the welfare of all fragments of family units, where the most defenseless gatherings are poor provincial families(Mulatu, 2016).

An increase in agricultural land use also leads to an increase in Nitrous Oxide emissions. Controlling Nitrous the releases from agrarian land usage without unfavorably affecting economic growth is a thoughtful policy task for Pakistan (A. Haider, ul Husnain, Rankaduwa, & Shaheen, 2021; H. Haider, 2021).

Agriculture is the life saver of Pakistan's economy, representing 19.5 percent of the total national output, utilizing 42.3 percent of the workforce and giving crude material to a few parts worth including. In this manner, it assumes a focal job in national advancement, nourishment security, and decreasing neediness. The rapid development of Pakistan's urban regions demonstrates that interest in high-esteem transient items such as natural products, vegetables, dairy, and meat is rising. The government is centering on expanding the yield for country cultivators through significant foundation speculations, including solid vehicle systems.

A. Ali and Erenstein (2017) large ranchers have additional land and a more noteworthy diversification of salary in addition to yields. In this way, Sajjad Ali et al. (2017) the sham for the rancher classification reveals that enormous subsistence ranchers have less hazard avoidance when compared with small subsistence ranchers. Subsequently, ranchers' financial components and other fiasco-related elements assume essential roles in deciding their hazard frame of mind. After the 2005 seismic tremor and major floods in 2010, Pakistan deprived the executives of catastrophes, readiness relief, and organized adapting systems (Hussain et al., 2023). It is significant that catastrophe chances decrease and readiness ought to be a national need. Moreover, it is mandatory that debacle-inclined zones be remembered for government bolster programs. Horticulture and nourishment safety can be influenced by changes in the atmosphere for several reasons, such as the conveyance of precipitation and accessibility of investment, water, biodiversity, land, and worldwide assets.

Environmental transformation is considered a worldwide marvel; as it may, its effects are more broadly felt in the creating nations, because of their increasingly noticeable susceptibility and the lesser capability to alleviate the effects of natural change. Since most nations also counting Pakistan are agribusiness based on economies, their horticultural segment is influenced the most by direct presentation to nature. Along these lines, the significant effect of environmental change is on horticultural creation because of changes in downpour design, temperature, floods, and dry seasons and negative impacts on water and land properties. The Himalayan ice masses (75%) softened and disappeared in 2035 (Ives, 2012).

Consequently, despite the increase in worldwide nourishment generation and security in the last three decades, more than 800 million individuals are still undernourished, and practically every one of them has a place with the creating nations(Organization, 2018). Moreover, the developing populace combined with the expanded power of extraordinary ecological events, such as floods, dry seasons, and outrageous changeability in temperature and precipitation, has pressed momentum nourishment generation frameworks and has compromised ebb and flow nourishment security in the vast majority of the developing nations. Because of higher nourishment requests and discounted crop efficiency, the higher nourishment costs may contrarily encourage nourishment access and accessibility for low pay and, as of now, poor family units.

In the same way as other creating nations, Pakistan is viewed as one of the nation’s generally influenced by nourishment weakness, neediness and ecological calamities. Around two-thirds of Pakistan's population lives in state zones, and straightforwardly or by inference depends on the agrarian division for their nourishment and job. Furthermore, a low versatility ability to oversee natural fires unfavorably influences agrarian efficiency and nearby nourishment security in Pakistan. As Pakistan is having growing population with a notable number of of youth that is active participant in the economy (Bencsik, Shujahat, & Juhász, 2021).

Market availability is one of the most significant factors influencing country nourishment security. They are regularly connected to different partners, such as processors, merchants, and retailers. As makers and buyers simultaneously, the showcase plays a two-path role for provincial family units. On the one hand, they utilize the market to purchase inputs or sell ranch produce, while, again, they use it to purchase nourishment and non-nourishment things to support their expectations for everyday comfort. Market access might be frustrated because of long ways from homesteads to showcases, transportation costs, and market data. Consequently, a better framework and simple market access can play a significant role in continuing neighborhood nourishment security through scaled down transportation and nourishment costs. Market access can be characterized in different ways, such as utilizing intermediaries for travel time, separation, and cost. Notwithstanding the market get to, access to other institutional administrations, such as augmentation and credit, is also essential to upgrade neighborhood access and usage of nourishment (Mobin & Ahmad, 2017).

Pakistan has two yield periods: Rabi crops are typically developed in the long stretches from November to April, and Kharif crops are developed from May to October. Thus, these two seasons make Pakistan an agrarian economy and its presentation relies on the atmosphere throughout the year. Environmental changes, for the most part, influence horticulture through changes in the temperature and rainfall.

African yields are increasingly sensitive to peripheral changes in temperature in contrast to changes in precipitation. For African yields, a temperature rise has beneficial outcomes, while a decrease in precipitation adversely influences net income. These perceptions depended on seven African field crops from 300 South African regions. Concentrate additionally recommended that one can move the developing period of a yield as per temperature; however, there is a likelihood that this sort of activity may prompt the total disposal of certain harvests from certain locales. According to these findings, farm households distinguish the increase in prices of food, harvest diseases, lack of water irrigation, and increase in health expenditures as major living risks (Ahmed, Ying, Bashir, Abid, & Zulfiqar, 2017; Sajjad Ali et al., 2017; Mohamed, 2017).

Environmental changes present significant risks to food security by altering the spatial and temporal distribution of rainfall, water availability, land, capital, biodiversity, and terrestrial resources. Such shifts in agricultural production could result in sustained vulnerability for an estimated nine billion people by 2050. Research indicates that both local and global water resources may be adversely affected by these environmental changes, potentially leading to inadequate water supplies for agricultural purposes.

Food security remains a significant policy issue within Pakistan's parliament, with a particular emphasis on wheat, maize, and rice as staple food crops, and sugarcane as the primary cash crop. This study examines the correlation between environmental variables—such as maximum and minimum temperatures, precipitation, humidity, and sunlight—and the yield of these key crops, including wheat, maize, rice, and sugarcane (Sajjad Ali et al., 2017)

Objective of the study

- The primary aim of this study was to examine the impacts of climate change, specifically through variations in precipitation, temperature, CO_2, and N_2O, on five principal agricultural crops in Pakistan: Cotton, Wheat, Rice, Maize, and Sugarcane.
- To check the climatic impact (through changes in precipitation, temperature, CO_2, and N_2O) on food security (based on livestock population, tractors, and availability of water).

Hypothesis for Testing:

H1: A causal relationship exists between climate change—encompassing temperature, precipitation, and emissions of carbon dioxide and nitrous oxide—and major agricultural crops, including cotton, wheat, rice, maize, and sugarcane.

H2: A causal relationship is also evident between climate change—specifically temperature, precipitation, and emissions of carbon dioxide and nitrous oxide—and food security, which involves factors such as livestock, population, tractors, and water availability.

METHODOLOGY AND DATA

This study utilizes the information of five significant harvests specific to the Wheat, Rice, Cotton, Maize and Sugarcane structures in Pakistan. The scientific information on production, kg/acre, and vectors of these crops and their optimum temperature and precipitation, carbon dioxide, and nitrous oxide were obtained from Pakistan economy surveys, world development indicators, and the meteorological department. This study applies descriptive statistics, mainly using secondary data from year (1980-2018). OLS and GLS techniques were used to capture the impact of discarded factors and cross-segment heterogeneity.

Theoretical Background

The concept of agricultural location encompasses both the spatial and allocative processes of land use by farmers, as well as the multidimensional organization of agricultural land uses. A key term in its traditional variants is economic rent, which denotes a form of surplus. Ricardo's theory emphasized the physical attributes of land and urban interests as primary factors in the generation of rent. In contrast, Von Thünen's model underscored the importance of distance from farms to markets, alongside transportation costs, crop types, market prices, and production costs as determinants of rent. Contemporary theories offer simplified models that explicitly describe the transportation of costs. However, this theory has faced criticism due to its numerous restrictive assumptions.

The hypothesis of agricultural locality theory represents an early effort to articulate a theory of spatial economics, dating back to the late eighteenth and early nineteenth centuries. This was when German economist von Thünen (1826) and British economist Ricardo (republished 1951) independently developed such theories. Given that agriculture was a primary sector of the economy, the origins of these concepts can be traced to early Chinese economic thought Kellerman (1989) and Von Glahn (2016) and foundational economic theories, such as those proposed by Adam Smith and Sir James Stuart (Barlowe, 1978; Eisenberg, 1956).

Model 1

Agriculture = f (climate change) ⟶ Eq. 1

Food security = f (climate change) ⟶ Eq. 2

Now, the main model of agriculture is:

$I\_PRO = \alpha_0+\alpha_1(I\_CC) +\alpha_2(TRC)+\alpha_3(WATER)$

where I_PRO is the index of major agricultural crop production, such as Cotton, Wheat, Rice, Maize and Sugarcane, as the dependent variable. I_CC is the index of climate change.

Model 2

$I\_Kg.ac = \beta_0+\beta_1(I\_CC) +\beta_2(TRC)+\beta_3(WATER)$

where I_Kg.ac is the index of kg/acre, which is dependent on major crops.

Model 3

$I\_hec = \gamma_0+\gamma_1(I\_CC) +\gamma_2(TRC)+\gamma_3(WATER)$

where I_hec is the index of the vectors of the main crops.

Dependent variables

C-Ton= cotton in tons.
M-PRO= maize in production.
R-PRO= rice in production.
S-PRO= sugarcane in production.
W-PRO= wheat in production.

} Index of crop production for agriculture.

Independent variables

TEM= temperature in %age.
PRE= precipitation in %age.
CO2= agricultural methane emissions in %age.
N2O= agricultural nitrous oxide emissions in %age.

} Proxies of climate change.

TRC= tractors in %age.
WATER= availability of water in %age.

} Proxies of agricultural inputs

Model 1 for food security

Dependent variable

Livestock=livestock production index (2004-2006) =100) in %age.

Independent variables

TEM= temperature in %age.
PRE= precipitation in %age. — Proxies of climate change.
CO2= agricultural methane emissions in %age.
N2O= agricultural nitrous oxide emissions in %age.
POP= population growth annual %age.
TRC= tractors in %age.
WATER= availability of water in %age.

Model 1

Livestock = $\varphi_0+\varphi_1(I\_CC)+\varphi_2(TRC)+\varphi_3(POP)+\varphi_4(WATER)$

Domesticated animals are regularly categorized as trained creatures brought up in a rural setting to distribute work and wares such as meat, eggs, milk, fur, leather, and wool.

Estimation Strategy

We used variables such as (cotton, maize, rice, sugarcane, and wheat) used as dependent variables, whereas temperature, precipitation, methane emissions of CO_2, nitrous oxide emissions, tractors, and availability of water were used as independent variables. However, the date of food security, in which livestock use is dependent on food security. After the variables, the integrated form of (1st difference) to create models that make stationary associations between the variables.

Stationarity Tests

The null hypothesis in the subsequent test posits that the number of co-combination vectors is $r = r^* < k$, in contrast to the alternative hypothesis that $r = k$. The testing is conducted sequentially for $r^* = 1, 2$, and so forth, and the first instance where the null hypothesis is not rejected is considered an estimate of r, with this initial non-rejection serving as a unit root test. The model may incorporate a trend term, a constant term, or both. To determine the (ADF) (1981) unit root tests for stationarity, lag selection is employed, which is a crucial step in formulating the equation. Subsequently, VAR is utilized to assess co-integration; if co-integration is detected in the model, the VEC model is then applied to determine whether the model exhibits short-run or long-run dynamics.

VAR selection Order Criteria

The Vector Error Correction (VEC) model is essentially a restricted form of the Vector Autoregression (VAR) model, tailored for use with nonstationary time series data that exhibit cointegration. The cointegration component, known as the error correction term, indicates the divergence from a long-term equilibrium, which is gradually rectified through a sequence of partial short-term modifications.

Vector Error Correction Model

VEC involves three steps in developing the VECM.

1) Lag selection criteria.
2) The Johansen Test of Co-integration.
3)- The VECM.

Lag selection criteria

AIC and SIC must be lower according to the selection of a lag, so we must also check * on the given value to determine better results.

Johansson Co-Integration Test

We moved on in the long run if any one of the values would be co-integrated. (iii) A vector mistake rectification (VEC) model is a limited VAR expected to be used with a nonstationary arrangement, which is known to be co-incorporated. We may test for co-coordination by applying an evaluated VAR object, equation object anticipated utilizing nonstationary relapse strategies, or by utilizing group object information. (see “Co-integration Testing”) Vector Autoregressive is a numerical technique used to inspect the relationship between a few inciting factors. Vector autoregressive (VAR) forms are general in financial aspects and different sciences because they are adaptable as basic models for multivariate time-arrangement information.

RESULTS AND DISCUSSION

The four models have been clarified in the previous section. The ADF test was used to check the unit roots. The result indicates that all the variables are indicated at the first difference, so the co-integration estimation technique has been applied to find the value of parameters, Vector Error Regression Techniques have been used, and the Wald test is used to check whether there is short- or long-run affiliation in the model. The LM test was used to check for serial autocorrelation and the covariance test was used to check for multicollinearity. Step-by-step techniques are described in this section. First, we begin the covariance test to check for multicollinearity in the model.

Correlation matrix of models 1, 2, and 3(for agriculture)

DI_CC	1		
DTRC	0.82936	1	
DWATER	-0.24452	-0.3625	1

The autocorrelation test is applied to check whether a correlation exists in model, 1, 2 and.3.

Model. 1		
I_PRO		
Lags:	**LM-Stat.**	**Prob.**
1	14.80676	0.5388
2	15.73719	0.4714
3	18.55914	0.2922
4	9.091670	0.9096
5	13.49812	0.6360
6	21.09038	0.1751
7	24.16602	0.0859
8	34.60337	0.0045
9	17.63544	0.3457

10	25.47039	0.0620
11	25.32469	0.0643

Null Hypothesis: there is no sequential correlation at lag order

Sample:1980-2018 involved obv.37

Model .2		
I_KG_AC		
Lags:	**LM-Stat.**	**Prob.**
	9.419571	0.8951
2	19.04902	0.2661
3	10.97520	0.8110
4	18.45506	0.2979
5	10.83830	0.8194
6	20.87738	0.1833
7	11.11661	0.8022
8	38.89841	0.0011
9	22.74637	0.1207
10	38.40958	0.0013
11	17.39556	0.3605

Null Hypothesis: no sequential correlation at the lag order.

Sample:1980-2018 involved obv.37

Model. 3		
I_HEC		
Lags:	**LM-Stat.**	**Prob.**
1	19.87667	0.2258
2	10.35663	0.8474
3	21.26121	0.1687
4	17.58326	0.3489
5	21.34882	0.1655
6	20.49421	0.1988
7	17.46537	0.3561
8	24.72069	0.0749
9	48.34258	0.0000
10	32.09019	0.0097
11	19.62099	0.2378

Null Hypothesis: here is no sequential correlation at the lag order

Sample:1980-2018, obv.37

According to models 1, .2 and 3 shows there is no sequential correlation at the lag order criteria.

Table 4: VAR Lag Selection Oder Criteria of Model.1 .2 and .3

Lag	LogL.	LR.	FPE.	AIC.	SC.	HQ.
I-PRO I-CC TRC WATER						
0	-266.9299	NA	62.19439	15.48171	15.65946	15.54307
1	-117.4347	256.2775*	0.030494*	7.853413*	8.742184*	8.160217*
2	-107.4070	14.89840	0.044619	8.194684	9.794470	8.746930
3	-89.94127	21.95687	0.045440	8.110930	10.42173	8.908619
I_KG_AC I_CC TRC WATER						
0	-282.5775	NA	152.0810	16.37586	16.55361	16.43722
1	-133.2860	255.9284*	0.075438*	8.759199*	9.647970*	9.066003*
2	-120.7992	18.55180	0.095912	8.959954	10.55974	9.512201
3	-111.3006	11.94110	0.153994	9.331463	11.64227	10.12915
I_HEC I_CC TRC WATER						
0	-270.7385	NA	77.31580	15.69934	15.87710	15.76071
1	-125.3945	249.1612*	0.048056*	8.308256*	9.197026*	8.615059*
2	-114.6676	15.93704	0.067563	8.609578	10.20937	9.161825
3	-95.84626	23.66114	0.063676	8.448358	10.75916	9.246046

The info criteria indicate lag order with respect to these three models (LR, FPE, AIC, SC, and HQ), supporting lag 1. Therefore, the Johansen cointegration test was used, and the outcomes are presented in table .5.

Johnson Cointegration Test Result for Model: I.1

Series: DI_PRO DI_CC DTRC DWATER				
Lags interval: 1 to 1				
The Unrestricted Cointegration of Rank Test (Trace)				
Hypothesized		Trace	(0.05)	
No. of CE(s)	Eigenvalue	Stat	Critical Value	Prob.**
None	.499663	47.32237	47.85613	0.0561
At most: 1	.366754	22.39333	29.79707	0.2772
At most: 2	.115278	5.945043	15.49471	0.7020
At most: 3	.041761	1.535687	3.841466	0.2153

Now, Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized		Max-Eigen	0.05	
No. of CE(s):	Eigenvalue.	Stat.	Critical Value.	Prob.*
None	.499663	24.92904	27.58434	0.1054
At the most: 1	.366754	16.44829	21.13162	0.1997
At the most: 2	.115278	4.409356	14.26460	0.8138
At the most: 3	.041761	1.535687	3.841466	0.2153

Rendering the cointegrated test here is no cointegration found in the model, so used Un Restricted VAR in Table 4.7.1.

Unrestricted VAR for model: 1.1

	DI_PRO	DI_CC	DTRC	DWATER
DI_PRO(-1)	0.383299	0.513460	-0.338009	0.000835
	(0.16531)	(0.17404)	(1.84580)	(0.00090)
	[2.31864]	[2.95027]	[-0.18312]	[0.92314]
DI_CC(-1)	0.377094	0.315184	0.352238	-0.001498
	(0.16238)	(0.17095)	(1.81303)	(0.00089)
	[2.32234]	[1.84374]	[0.19428]	[-1.68647]
DTRC(-1)	0.015702	-0.007589	1.059215	-1.30E-05
	(0.00418)	(0.00440)	(0.04665)	(2.3E-05)
	[3.75794]	[-1.72517]	[22.7032]	[-0.56782]
DWATER(-1)	20.09351	-1.888598	-368.2752	0.842317
	(15.1689)	(15.9697)	(169.370)	(0.08299)
	[2.32465]	[-0.11826]	[-2.17438]	[10.1492]
C	-8.000586	3.675897	40.65976	0.022985
	(2.92220)	(3.07646)	(32.6281)	(0.01599)
	[-2.73786]	[1.19485]	[1.24616]	[1.43762]
R-squared:	0.974888	0.869682	0.996950	0.837197
Adj. R-squared:	0.971749	0.853392	0.996569	0.816847
Sum of sq. resids:	47.47956	52.62463	5919.288	0.001421
S.E. equation:	1.218087	1.282388	13.60065	0.006665
F-statistic:	310.5706	53.38840	2615.161	41.13925
Log likelihood:	-57.11428	-59.01765	-146.3892	135.5906
Akaike AIC:	3.357529	3.460414	8.183201	-7.058952
Schwarz SC:	3.575220	3.678105	8.400893	-6.841260
Mean dependent:	-0.081031	0.080252	410.4717	0.109842
S.D. dependent:	7.247028	3.349203	232.1940	0.015573
Determinant of resid covariance (dof adj.)”		.014527		
Determinant of resid covariance:		.008127		
Log likelihood:		-120.9715		
Akaike information of criterion:		7.620083		
Schwarz of criterion:		8.490850		

According to the results, there is no cointegration in the model. Thus, no long-run affiliation exists, but all variables have a positive and significant impact on crop productivity with respect to the independent variables. productivity is positive and negative with reference to their stages. This nonlinear relationship can be estimated using the Cobb–Douglas production function (Mahmood, Ahmad, Hassan, & Bakhsh, 2012). The effects of changes in temperature and precipitation fundamentally differ with the planning and creation of yields (Kaisa, 2025).

4.6 Johnson Cointegration Test Result for Model: 1.2

The Unrestricted Cointegration Rank Test (Trace):				
Hypothesized		Trace	(0.05) of the	
No. of CE(s):	Eigenvalue.	Stat.	Critical Value.	Prob.*
None *	.583178	56.94419	47.85613	0.0056
At the most: 1	.414115	25.44075	29.79707	0.1463
At the most: 2	.128523	6.193984	15.49471	0.6726
At the most: 3	.033901	1.241607	3.841466	0.2652

Here is the Trace test which specifies only 1 of the cointegrating eqn(s) are at the level of 0.05

The Unrestricted Cointegration Rank Test (Maximum Eigenvalue):				
Hypothesized		Max-Eigen	(0.05) of the	
No. of the CE(s):	Eigenvalue.	Stat.	Critical Value.	Prob.*
None *	.583178	31.50345	27.58434	.0149
At the most: 1	.414115	19.24676	21.13162	.0899
At the most: 2	.128523	4.952377	14.26460	.7478
At the most: 3	.033901	1.241607	3.841466	.2652

Here is cointegration 1, which means that we use VECM.

According to the VECM model, we check whether there is a short- or long-run effect in the given model. Therefore, we applied the Wald test to check for short- and long-run causality in the model. According to the results, there was no short-run causality from DI_CC, DTRC, and DWATER to I_KG_AC.

4.6 Johnson Cointegration Test Result-Model 1.3

Series: I_HEC I_CC TRC WATER				
Lags interval: 1 to 1				
Hypothesized the		Trace	(0.05) of the	
No. of CE(s):	Eigenvalue.	Stat.	Critical Value	Prob.*
None *	.457792	47.92108	47.85613	.0493
At the most: 1	.435617	25.88529	29.79707	.1322
At the most: 2	.113370	5.292490	15.49471	.7770
At the most: 3	.026333	0.960698	3.841466	.3270

The Trace test indicates only 1 cointegrating eqn(s) are at the level of 0.05

The Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized the		Max-Eigen	(0.05) of the	
No. of CE(s)	Eigenvalue.	Statistic.	Critical Value	Prob.*
None:	.457792	22.03578	27.58434	.2185
At the most: 1	.435617	20.59280	21.13162	.0593
At the most: 2	.113370	4.331793	14.26460	.8228
At the most: 3	.026333	0.960698	3.841466	.3270

Max-eigenvalue test which specifies that there is no cointegration are at the level of 0.05

Regarding the cointegration test, there is an existing cointegration association if the critical value is superior to that of the Traced test or if the p-value is less than 5%. On the off chance that one P-value is slighter than 5%, at that point the cointegration rank is one, in the event that two P-values are less than the 5% critical level, at that point the cointegration rank is two, etc. According to Table 6, one cointegration exists among the variables in the Johansen cointegration test.

The data presented in Table 4.5 demonstrate the results of the Johnson Cointegration analysis, wherein the null hypothesis Ho: r = 0 is significant for the Trace Test (Cointegration Rank Test). This significance leads to the rejection of the null hypothesis Ho: r = 0 (indicating no cointegration), thereby confirming that all variables are indeed cointegrated. Similarly, these variables also exhibit cointegration in the maximum eigenvalue test. Consequently, the variables maintain a long-term relationship. The results of the Vector Error Correction Model, detailed in Table 4.6, provide insights into the short-term equilibrium.

4.7 Vector Error Correction Model Results-Model I.2 and 1.3

Table no. 4.6 VECM Result

Model :1.2 DI_KG_AC	
CointEq1	(0.19728) (-5.52665)
I_CC(-1)	(0.14502) [4.64108]
TRC (-1)	(0.00253) [-13.5937]
WATER(-1)	(16.9417) [-1.10929]
C	14.6654
Model :1.3 I_HEC	
CointEq1	(0.24199) [-4.06561]
I_CC (-1	(0.13257) [-5.59998]
TRC (-1)	(0.00231) [-3.24400]

WATER (-1)	(15.4328) [-6.61392]
C	4.552418

According to Model 1.2, tractors are highly significant and negative; all variables are significant and negative in Models 1.2 and 1.3, but the index of climate change is positively significant. Negative effect of driving heavyweight machinery on soil used for growing plants. Soil compaction is considered to be due to increased soil thickness, decreased air volume, and a reduced ability to sewer off excess water. Heavy agricultural equipment causes permanent damage to the soil. This may lead to an increased pollution rate from agricultural land areas, poorer crop yields, and permanent compaction damage caused by the machine loads (Liu, 2024).Some climatic factors adversely and essentially influence harvest yield, whereas others are not critical. However, the effect of temperature was certain and noteworthy for all the yields. Nourishment and openness to water are profoundly helpless in rapidly changing environments (Sajjad Ali et al., 2017). Decreased water accessibility adjusts yield and cropping patterns. (Government of Pakistan, Ministry of Environment). Nourishment security, which is commonly overlooked, is essential to countrywide security (Government of Pakistan Ministry of Environment 2010).

According to the cointegration test, a cointegration relationship is established if the critical value exceeds the actual test value or if the P-value is below 5%. A cointegration rank of one is indicated if one P-value is under 5%, while a rank of two is indicated if two P-values fall below the 5% threshold. As demonstrated in Table 6, the Johansen Cointegration test reveals a single cointegration among the factors. The results in Table 4.6, model 1.1, present the Johansen Cointegration findings, where the hypothesis Ho: r = 0 is significant for the Trace Test (Cointegration Rank Test), leading to the rejection of the hypothesis Ho: r = 0 (no cointegration), thereby confirming that all variables are cointegrated. Similarly, the variables are also cointegrated according to the maximum eigenvalue test. When variables are cointegrated, it implies a sustainable long-term relationship among them. Consequently, the Vector Error Correction Model results, detailed in Table 4.7, provide insights into short-term equilibrium.

Wald test

Dependent variable			Remarks
DI_KG_AC Model: 2	Null hypothesis	Probability >5% or <5%	Short run or not
Independent variable			
DI_CC	C(3)=0	0.7308	No short run
DTRC	C(4)=0	0.2799	No short run
DWATER	C(5)=0	0.5186	No short run
			Dependent variable
DHEC model:3			
Independent variable			

DI_CC	C(3)=0	0.1023	No short run
DTRC	C(4)=0	0.8109	No short run
DWATER	C(5)=0	0.0209	Short run

If C (1) is significant and negative in sign, then it implies that there is a long-run connectedness running from independent to dependent variables. For example, in model 1.1, DI_KG_AC has a coefficient of C(1) of -5.5266, which means that this coefficient is significant and negative in sign, which means that there is a long-run relationship in model 1.2. Which is I_KG_AC

As in Model 1.3, which is I_HEC here, the coefficient of C (1) is -4.06561, meaning that long-run affiliation exists in this model. If the p-value is greater than 0.05, it implies that there is no short run in the model. If the p-value is less than 0.05, it indicates that a short run exists in the model. A short run existed in the water of Model 3. According to the Wald test, there is no short-run causality running from I_CC to vectors or TRC; however, there is a short run in the model from water to vectors.

Correlation matrix of model 2 (food security):

LIVESTOCK				
	DI_CC	DPOP_	DTRC	DWATER
DI_CC	1			
DPOP_	-0.9320	1		
DTRC	0.8293	-0.8138	1	
DWATER	-0.24452	0.05904	-0.3625	1

The autocorrelation test is applied here to check a correlation exists in the model, 2

Model 2		
LIVESTOCK		
Lags:	**LM-Stat.**	**Prob.**
1	19.81223	.7566
2	37.37989	.0531
3	24.09791	.5137
4	38.00534	.0462
5	24.21966	.5067
6	39.29920	.0344
7	33.35518	.1224
8	40.51750	.0258
9	43.49936	.0123
10	28.54596	.2833
11	49.37889	.0025
VAR Residual Serial Correlation LM Tests		
Null Hypothesis: no serial correlation at the lag order.		
Sample:1980-2018, obv.37		

According to Model 2, there is no sequential correlation for the lag order criterion.
Lag criteria for food security

LIVESTOCK						
Lag:	LogL.	LR.	FPE.	AIC.	SC.	HQ.
0	-287.5529	NA	12.52843	16.71731	16.93950	16.79401
1	-30.34798	426.2253	2.20e-05	3.448456	4.781611	3.908661
2	13.15310	59.65862	8.39e-06	2.391251	4.835370	3.234961
3	63.50444	54.66717*	2.55e-06*	0.942603*	4.497684*	2.169817*

The informational principles indicate a lag order. Four support lags (LR, FPE AIC, and HQ) of 3. Therefore, the Johansen cointegration test was used, and the outcomes are presented in Table.

Johnson Co-integration Test Result of given Model:2

Lags interval (in first differences): 1 to 3				
Hypothesized No. of CE(s).	Eigenvalue.	Trace Stat.	0.05 Critical Value.	Prob.*
None *	.749062	132.0298	69.81889	0.0000
At the most:1 *	.633375	85.02318	47.85613	0.0000
At the most :2 *	.496148	50.90706	29.79707	0.0001
At the most :3 *	.351625	27.60100	15.49471	0.0005
At the most :4 *	.315118	12.86927	3.841466	0.0003

Trace test specifies that the 5 cointegrating eqn(s) at the level of 0.05

Hypothesized No. of the CE(s).	**Eigenvalue.**	**Max-Eigen Stat.**	**0.05 Critical Value.**	**Prob.***
None *	.749062	47.00661	33.87687	0.0008
At the most:1 *	.633375	34.11611	27.58434	0.0063
At the most :2 *	.496148	23.30607	21.13162	0.0243
At the most :3 *	.351625	14.73173	14.26460	0.0422
At the most :4 *	.315118	12.86927	3.841466	0.0003

Max-eigenvalue test that specifies 5 cointegrating eqn(s) at the level of 0.05

According to cointegration test here is existing cointegration association on the off chance that the Critical is value more prominent than the P-value or Trace test lessor than the 5%. In the event that one P-value is slighter than 5%, at that point the cointegration rank is one, in the event that two P-values which are 0.024 and 0.042 is lesser than 5% significant level, at that point the cointegration rank is two, etc. Along these lines, we apply VECM.

Model 2: LIVESTOCK	
Variable	t-statistics in [ ] standard error in ( )
CointEq1	(0.17352) [-1.88389]

I_CC (-1)	(0.62146) [-2.58159]
POP	(3.05157) [2.93376]
TRC (-1)	(0.00580) [-19.0313]
WATER (-1)	(52.5143) [-2.56675]
C	-47.98283

The cointegration result specifies the presence of cointegration among the variables and suggests a long-run connotation among the variables. Thus, the VECM model can be smeared. The mistake rectification term reveals the speed at which our model returns to adjust following an exogenous shock. This should be a negative sign, demonstrating an exchange of harmony. The positive transfer of ownership determines the development of the balance. On the off chance that C (1) is negative in sign and should be huge, we will have the option to state that here is for quite some time run causality running from ICC, POP_, WATER to Dependent variable, which is livestock.

There is no p-value to check whether the null hypothesis is rejected or accepted. Therefore, we applied the Wald test to check the p-value.

According to the Wald test, we cannot reject the null; rather, we admit it because C (5) =C (6) =C (7) is zero. There is no short-run connectedness, which is successively from I_CC to LIVESTOCK.

Currently, there is no successive short-run connectedness from the population and tractors to livestock, but water has short-run connectedness running from DWATER to LIVESTOCK.

Wald Test			
Dependent			Remarks
DLIVESTOCK	Null hypothesis	Probability >5% or <5%	Short run/not
Independent			
DI_CC	C(5)=C(6)=C(7)=0	0.2676	No short run
DPOP_	C(8)=C(9)=C(10)=0	0.3653	No short run
DTRC	C(11)=C(12)=C(13)=0	0.0973	No short run
DWATER	C(14)=C(15)=C(16)=0	0.0305	Short run

Model 1 exhibits long-term causality in relation to food security. This is substantiated by the coefficient of C (1), which is -1.88389, signifying that C (1) is negative and approaches the threshold of significance. Therefore, the model indicates the existence of a long-term relationship between the independent variables and the dependent variable. According to the model, no short-run association exists, except for DWATER, because the value of water is less than 5%, which indicates the existence of a short run.

CONCLUSION

The present study concludes that both climatic and non-climatic factors exert a significant influence on the five principal agricultural crops, as measured by production per kilogram per acre and hectare. This finding suggests that climate change impacts agricultural crops and food security in both advantageous and adverse manners (Farooq et al., 2022). The pronounced effect of environmental changes on agricultural production is attributed to variations in rainfall patterns, temperature fluctuations, floods, droughts, and negative impacts on land and water resources (Sajjad Ali et al., 2017). These environmental changes pose a considerable threat to the sustainability of diverse ecosystem types and the viability of livestock production systems across many regions globally.

Greenhouse gases (GHG) are mutually liquidated in the climate by characteristic `foundations and anthropogenic (human-linked) exercises. Decreasing the increment of GHG emissions from agribusiness, particularly domesticated animal generation, ought to be a top need, since it could check for warming reasonably quickly. Among GHGs, CH_4 is viewed as the largest potential supporter of dangerous atmospheric deviation levels. As S. Ali and Reardon (2013) Pakistan is amount few countries facing the ripples of energy shortages due to environmental and international defense and diplomatic maneuvers. It demands the policy support from the developed nations.

Ruminant animals, such as dairy cattle, wild ox, sheep, and goats, contribute significantly to the outflow of methane from farming. However, water availability has a negative impact on kg/acre and livestock.

Environmental changes only slightly affected the yield of the significantly nourished crops. Approximately 60% of the Pakistani population resides below the neediness line. According to these findings, the study suggest that the concerned department should provide a sufficient amount of water for better crop production and food security. Government policies should address the challenge of decrease Co_2 and N_2O emissions to increase agricultural and livestock production.

REFERENCES

Afzal, M. (2009). Population growth and economic development in Pakistan. *The Open Demography Journal, 2*(1), 1-7.

Ahmed, U. I., Ying, L., Bashir, M. K., Abid, M., & Zulfiqar, F. (2017). Status and determinants of small farming households' food security and role of market access in enhancing food security in rural Pakistan. *PloS one, 12*(10), e0185466.

Ali, A., & Erenstein, O. (2017). Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management, 16*, 183-194.

Ali, S., Amjad, M., Kiani, A., & Wei, L. (2017). Noise Destroying the Peace of North

Pakistan. *Journal of Applied Environmental and Biological Sciences, 7*(8), 74-79.
Ali, S., Liu, Y., Ishaq, M., Shah, T., Abdullah, Ilyas, A., & Din, I. U. (2017). Climate change and its impact on the yield of major food crops: Evidence from Pakistan. *Foods, 6*(6), 39.
Ali, S., & Reardon, J. (2013). Pakistan's energy dilemma: a call for global support. *International Journal of Green Economics, 7*(3), 241-256.
Ali, S., & Reardon, J. (2023). Perceived barriers to the Islamic concept of sustainability. *INDONESIAN JOURNAL OF SUSTAINABILITY, 2*(1), 36-44.
Barlowe, R. (1978). Land resource economics: The economics of real estate.
Bencsik, A., Shujahat, A., & Juhász, T. (2021). Y–Z in the labour market: employee perceptions in different cultures (Hungary–Pakistan). *Business: Theory and Practice, 22*(2), 453-461.
Borras Jr, S. M., & Franco, J. C. (2012). Global land grabbing and trajectories of agrarian change: A preliminary analysis. *Journal of agrarian change, 12*(1), 34-59.
Eisenberg, J. N. (1956). *British Theories of Economic Growth from Adam Smith to John Stuart Mill*: Wayne State University.
Farooq, M. S., Uzair, M., Raza, A., Habib, M., Xu, Y., Yousuf, M., . . . Ramzan Khan, M. (2022). Uncovering the research gaps to alleviate the negative impacts of climate change on food security: a review. *Frontiers in plant science, 13*, 927535.
Haider, A., ul Husnain, M. I., Rankaduwa, W., & Shaheen, F. (2021). Nexus between nitrous oxide emissions and agricultural land use in agrarian economy: An ardl bounds testing approach. *Sustainability, 13*(5), 2808.
Haider, H. (2021). Education, conflict, and stability in South Sudan.
Hussain, M. A., Shuai, Z., Moawwez, M. A., Umar, T., Iqbal, M. R., Kamran, M., & Muneer, M. (2023). A review of spatial variations of multiple natural hazards and risk management strategies in Pakistan. *Water, 15*(3), 407.
Ives, J. D. (2012). Environmental change and challenge in the Himalaya. A historical perspective. *Pirineos, 167*, 29-68.
Kaisa, P. (2025). Environmental Pressure-Network Theory: A Unified Framework for Understanding Cultural-Technological Development. *Available at SSRN 5287812*.
Kellerman, A. (1989). Agricultural location theory 1: basic models. *Environment and Planning A, 21*(10), 1381-1396.
Liu, K. (2024). Parameters optimisation of agricultural machinery for soil compaction mitigation and crop yield enhancement.
Mahmood, N., Ahmad, B., Hassan, S., & Bakhsh, K. (2012). Impact of temperature ADN precipitation on rice productivity in rice-wheat cropping system of Punjab province. *J. Anim. Plant Sci, 22*, 993-997.
Mobin, M. A., & Ahmad, A. U. F. (2017). Achieving sustainable economic development through Islamic microfinance and the potential of a proposed

two-tier mudarabah waqf business model. In *Handbook of empirical research on Islam and economic life* (pp. 193-212): Edward Elgar Publishing.

Mohamed, A. A. (2017). Food security situation in Ethiopia: a review study. *International journal of health economics and policy, 2*(3), 86-96.

Mulatu, A. (2016). On the Concept of'Competitiveness' and its Usefulness for Policy. *Structural Change and Economic Dynamics, 36*, 50-62.

Organization, W. H. (2018). *The state of food security and nutrition in the world 2018: building climate resilience for food security and nutrition*: Food & Agriculture Org.

Von Glahn, R. (2016). *An economic history of China: From antiquity to the nineteenth century*: Cambridge University Press.